there may be distinct geographic and/or demographic markets for which low cost Little LEO satellites provide the best solution.

In the higher end markets, where near real time service is required and there is little demand elasticity, few if any substitutes and only two current commercial competitors, entry of additional Little LEO competitors will be essential to ensuring continued pressure on price. The high value of additional competition in these submarkets underscores the need to make additional spectrum available to second round licensees so that they can effectively enter these submarkets and be fully competitive across the full range of applications.

These assessments are not altered by the fact that additional Little LEO systems may be authorized by foreign administrations. It is the U.S. customer that is at issue, and there is no certainty as to if or when, or in which submarkets, any foreign Little LEO systems will serve the U.S. market.

Consequently, Final Analysis believes that application of SCP principles to the Little LEO industry clearly indicates that the Commission should endeavor to license as many new entrants out of the second round as possible. This will introduce at least four new companies to the market. Some of them will continue to focus on the lower end, intermittent services. Some of them, including Final Analysis, will be positioned to provide near real time services to the greatest extent possible, subject to future availability of additional spectrum. Because each of the new second round applicants has a slightly different business plan, the Commission should not take on the responsibility of trying to determine, at this point, which one of them will survive and/or be the most successful competitors in the future.

In contrast, there is no indication under accepted economic theory that the contrary approach, i.e., reverting available WARC-92 spectrum to first round licensees, can be expected to have any particular public benefits. The first round licensees may be able to achieve greater economies of scale and scope if they received the remaining spectrum from WARC-92. But in reality, they would apply the additional spectrum to system expansion in the year 2000 or later, and the market will be very different then. Also, there is no evidence whatsoever that this additional expansion will have any measurable public benefit in terms of wider availability or lower price of Little LEO services.

In any event, consideration of such a tradeoff between achievement of economies of scale and scope and the benefits of increasing competition is not appropriate in the context of Little LEO, which is at the very beginning of market development. Such a tradeoff analysis has usually been applied, if at all, in the context of evaluating mergers of firms in established industries. Such analysis invokes the "Williamsonian Welfare Tradeoff," which is the hope that efficiency gains from merger will more than offset the reduction in competitors.[13] The "tradeoff" assumes that the prices to consumers will tend to increase because of greater

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[13] Oliver E. Williamson, "Economies as an Antitrust Defense: The Welfare Tradeoffs," *American Economic Review*, Vol. 58, No. 1 (March 1968), pp. 18-36.

market concentration. Antitrust authorities have indeed recently contemplated the use of such a model. However, a difficulty with the "tradeoff" is that welfare gains and losses cannot be accurately measured, even in established markets.[14] Furthermore, the "tradeoff" accepts wealth transfers from customers to monopolies as long as efficiency is not impaired.[15] Given the controversy entailed in the use of such an approach even in established markets, the public interest would not be well served to do so in markets that will emerge only in the future.

V. Conclusion

This Market Analysis indicates that additional competition can be extremely beneficial in the Little LEO industry. There are no indications that all of the second round applicants, if licensed, could not be sustained in the market. However, under the constraints of currently available spectrum, a Little LEO market that included up to four additional licensees would still be imperfectly competitive. There would still be undesirable concentration in submarkets, as only the first round licensees realistically will be able to provide near real time services for the next several years.[16]

Consequently, in this proceeding, the FCC should adopt policies that (i) promote eventual achievement of effective competition across the full range of Little LEO applications; (ii) ensure that all Little LEO licensees can look forward to competition on a level playing field; (iii) create incentives that reward technical innovation and international promotion of Little LEO services generally; and (iv) accept that development of full and effective competition in Little LEO markets will be incremental.

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[14] Alan A. Fisher and Robert H. Lande, "Efficiency Considerations in Merger Enforcement," *California Law Review*, Vol. 71, No. 6 (December 1983), pp. 1582-1706.

[15] Alan A. Fisher, Frederick I. Johnson, and Robert H. Lande, "Price Effects of Horizontal Mergers," *California Law Review*, Vol. 77, No. 4 (July 1989), pp. 777-827.

[16] As explained in the technical analysis set forth in Exhibit 2 to these Comments, within the spectrum available in this proceeding, second round licensees will be inhibited in the provision of near real time services because, by the time full constellations can be deployed (approximately four to five years from the date of license), frequency bands bands available for exclusive use by Little LEOs must begin to be shared with NOAA satellites that are scheduled to migrate into that spectrum.

EXHIBIT 2

SYSTEMS ANALYSIS

FINAL ANALYSIS COMMUNICATION SERVICES, INC.

I. INTRODUCTION

Final Analysis Communications Services, Inc. ("Final Analysis") has prepared this detailed Systems Analysis in response to the Commission's Notice proposing a spectrum sharing plan rules for the second processing round of the Non-Voice, Non-Geostationary Mobile Satellite Service ("NVNG MSS" or "Little LEO").[1] The Commission has proposed three distinct systems (hereinafter "Little LEO-1" "Little LEO-2 and Little LEO-3"), each of which has its own characteristics.[2] This Systems Analysis provides a careful review and detailed analysis of each system. This Systems Analysis reflects the combined efforts of an independent study of the Commission's proposals performed at Final Analysis's request by Autometric, Inc. (hereinafter, the "Autometric Study"), provided hereto as Attachment A, as well as Final Analysis's in-house technical review. Based on Final Analysis's in-house review and the independent Autometric Study, we conclude that the Commission's proposals: (i) form a useful basis for assigning spectrum in this processing round, but in their present form do not adequately address certain unique characteristics of Little LEO systems; and (ii) are not sufficient to support a fully competitive environment for Little LEOs across all market subsegments; and (iii) unnecessarily create problems of mutual exclusivity.

II. GENERAL OBSERVATIONS

A. Insufficiency of Little LEO Spectrum Allocations

Final Analysis supports the Commission's efforts to initiate service for second round Little LEO licensees. However, the Notice's spectrum proposals fall short of the total amount of spectrum necessary to provide the full constellation of services that will meet market demand or that first round Little LEO licensees will be able to provide. Variances in other significant factors of the proposed systems will impede fair and direct competition for Little LEO

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[1] See Amendment of Part 25 of the Commission's Rules to Establish Rules and Policies Pertaining to the Second Processing Round of the Non-Voice, Non-Geostationary Mobile Satellite Service, Notice of Proposed Rulemaking, IB Docket No. 96-220, FCC 96-426 (released October 29, 1996) ("Notice").

[2] See id. at Section III.B, ¶¶ 41-77.

services. Specifically, Little LEO operations will require more spectrum for service uplink operations than for service downlink operations, and full constellation operations will require more dedicated feeder link spectrum.

Service Uplink-to-Downlink Ratios. A study presented at the recent ITU-R's Working Group 8D meeting, provided as Attachment B hereto, shows that the ratio of service uplink-to-downlink spectrum required for commercial Little LEO operations will be approximately 2-to-1.[3] There are several reasons why service uplink operations demand more capacity than service downlink operations. For example, automated meter reading, environmental data collection, and asset tracking will require a batch of uplinks from individual assets, and one mass downlink to the gateway station via the feeder link.

Dedicated Feeder Links. Dedicated feeder links are critical to commercial Little LEO operations.[4] Feeder links are necessary for continuous communications between an operational spacecraft and at least one gateway to provide, among other things, for the real-time relay of messages between users and the gateway.[5] Moreover, at least 50 kHz of spectrum is required per satellite per direction (uplink or downlink), with three satellites overlapping in the same footprint, three separate dedicated links per direction are required for full constellation operations.[6] While feeder link spectrum may be shared among satellites in the same system,

[3] Uplink operations on a shared basis will require approximately 13.6 MHz of spectrum while downlink operations on a shared basis will require approximately 7 MHz of spectrum. See Sub-Working Group 8D3A-6, Spectrum Demand for Non-GSO MSS Below 1 GHz Services at §§ 3.1-3.2 (November 5, 1996) ("Working Group 8D Study").

[4] A feeder link is

> . . . a radio link from an earth station at a given location to a space station, or vice versa, conveying information for a space radiocommunication service other than for the fixed satellite service. The given location may be at a specified fixed point, or at any fixed point within specified areas.

47 C.F.R. § 2.1.

[5] See Report of the Below 1 GHz LEO Negotiated Rulemaking Committee at 6 (September 16, 1992) ("Below 1 GHz Negotiated Rulemaking Report").

[6] Three satellites with overlapping footprints in a typical Little LEO system would require at least 150 kHz (in each direction) of spectrum dedicated on an exclusive basis to feeder link

it is "practically impossible to share feeder link spectrum with another system."[7] Sharing of feeder links among multiple Little LEO systems would result in random satellite visibility and unacceptable system outages.[8] Yet, the Commission's proposed spectrum sharing plan requests the Little LEO systems to share feeder link spectrum on an intersystem basis. Further, not all of the proposed systems have the minimum required spectrum for feeder link operations.

B. Service Outages

Final Analysis's in-house technical review and the independent Autometric Study show that the Commission's proposal would provide maximum communication service coverage levels of approximately 65 percent of time, resulting in extended outages which are particularly unacceptable for the near real time applications. The resulting communications service outages in the systems proposed in the Notice for the second round Little LEO licensees, therefore, would limit second round Little LEO licensees to serving only a fraction of the total market. Furthermore, the Commission's proposed systems vary in the degree of communication service levels. These variations in communications service levels exist among the three proposed

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operations.

[7] See Below 1 GHz Negotiated Rulemaking Committee Report at 6.

[8] As the Commission notes, intersystem sharing of feeder link spectrum among multiple Little LEO systems would require Little LEO licensees

> to pre-coordinate on an uplink signal structure, including packet rates, modulation techniques and signalling techniques. It would also be necessary to attempt to coordinate actual frequency use operationally on a real time basis, since there would be times when there would be a need to share the uplink data rate among numerous satellites (two or more from each system), thereby effectively resulting in system outages. *However, such intersystem operational coordination would be difficult since the satellites from the different systems will not be station-kept with respect to each other. The arguments of perigee and right ascension of ascending nodes will be uncoordinated, and will precess at different rates, making simultaneous visibility a likely but random event with respect to the busy hours of traffic loading.*

Little LEO Notice 8 FCC Rcd 6330 at n.28 (emphasis added); see also Below 1 GHz Negotiated Rulemaking Report at 6-7.

systems proposed in the Notice, as well as between the three systems and the first round Little LEO licensees.

Furthermore, the large outages in the systems proposed in the Notice for second round Little LEO licensees constantly change and affect every location on the globe and at every hour of the day. In contrast, first round Little LEO licensees have virtually uninterrupted service[9] capability around the globe and around the clock, based only on the constellation size and orbit characteristics. Thus, first round licensees will be able to serve all market segments, while second round operators will not.

C. Operations Complexity and Costs

The Commission's spectrum sharing proposal significantly increases the data message operations within the Little LEO ground system. User requests for data message services are scheduled according to the user requirements and the satellite coverage. The spectrum sharing proposal dynamically alters which satellites can serve specific customers at specific times. Consequently, the amount of planning and uplink of instructions to the satellite will increase dramatically.

D. Feasibility of TDMA/FDMA Sharing

The Commission's proposed framework would require second round Little LEO licensees to share with existing first round licensees as well as governmental users. Sharing techniques proposed in the Notice, TDMA and FDMA, cannot feasibly support shared commercial operations of multiple licensed Little LEO systems as proposed. Both TDMA and FDMA are mainly intra-system sharing techniques. That is, they are useful within a particular system to effectively manage a limited communications resource, such as frequency spectrum. Multiple access among multiple Little LEO systems, in contrast, necessitates remote sharing of a communications resource under dynamic, real time conditions. Under such conditions, a system controller must remain continuously aware of each user's needs. The amount of time this information transfer requires creates an overhead and upper limit on efficient spectrum utilization. For FDMA and TDMA to operate on an intersystem basis, therefore, would require a master controller operating across system boundaries. Such an arrangement would deprive the various Little LEO systems of their independence and their ability to create differentiation strategies to compete. Such a limited arrangement, moreover, would not support a viable and competitive, multi-system Little LEO marketplace.

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[9] That is, small communication outages of only a few minutes exist under the full constellation systems proposed by Orbcomm and Starsys.

III. REVIEW OF PROPOSED SYSTEMS

A. Little LEO-1

The Commission proposes Little LEO-1 as a system which shares frequencies with VITA using TDMA/FDMA techniques. Aside from the concerns of intersystem sharing of spectrum using TDMA/FDMA as discussed earlier, we also find that the proposed system has significant service outages, and that there is a lack of sufficient spectrum to conduct even basic feeder link communications for a satellite.

Service Outages. Our analysis of the service impact due to frequency sharing with VITA's one satellite shows the impact to be significant. Specifically, the average global operational time for the TYPSAT[10] constellation is 78%. This is contrary to the Commission's estimates. We believe the Commission's estimates were calculated based on user visibility from a fixed point. This does not accurately model the interference potential, as a user may not be in view of a VITA satellite, yet a TYPSAT's footprint can still overlap with the footprint of VITA's satellite. It is the overlapping footprint conditions that restrict service transmissions. We further note that the service outage will increase when VITA launches its second satellite, upon Commission approval.

We note that the service outage is variable over time and geographic location, creating service consistency issues and adding to operations cost and complexity as noted earlier. We also note that there are cases where up to four (4) satellites are restricted from operations for 100% of a 24-hour period, and other cases where all but five (5) of the twenty-four (24) satellite constellation are affected with over 20% service outage time at some point in a 24-hour period.[11] This demonstrates the dynamics of the service outage condition, and the resulting impact on operations.

A service outage of 22% effectively impedes the applicant from offering the same real-time or near-real time service as first round Little LEO licensees. This service outage would preclude a second round Little LEO licensee from serving significant customer

[10] "TYPSAT" refers to a representative Little LEO satellite constellation used for purposes of comparative analysis in the Autometric Study. TYPSAT was modeled as a 24 satellite constellation in four planes of six satellites each, equally spaced.

[11] The TYPSAT constellation altitude was modeled at 1000 kilometers, which is the same as VITASAT-1R. Should the proposed Little LEO constellation altitude be significantly less, then the service outage may be reduced.

submarkets.

Spectrum Allocation. We note that the VITA service is limited by design in its coverage and the extent of the services it provides. VITA will not be utilizing separate feeder link spectrum.[12] In addition, due to the limited market segment that VITA will address, its spectrum requirements are modest. The Negotiated Rulemaking Report also states that "because of the system technology and operational constraints, it would be practically impossible to share the gateway (feeder link) spectrum with another (NVNG) system."

On the other hand, the commercial systems proposed by all the second round applicants require much broader coverage for a much broader customer base and service offering. Based on the demand studies recently reported at the ITU-R Working Group 8D Fall 1996 meeting in Geneva, a total of about 25 MHz is needed for shared service links and dedicated feeder links. See Attachment B. The amount of spectrum proposed for Little LEO System-1 does not meet even the minimum feeder link needs, not to mention the significant service link needs with a 2-to-1 ratio of uplink to downlink spectrum. Therefore, the service outage characteristics of Little LEO-1, even under sharing conditions with one VITA satellite, would preclude the implementation of a commercially viable Little LEO system.

B. Little LEO-2

The Little LEO-2 proposal in the Notice reflects allocation of a portion of the 148.0-149.9 MHz uplink and the 137-138 MHz downlink band. An operator licensed to this system would be required to engage in time-sharing with NOAA of the 137-138 MHz band, and with other users of 137-138 MHz downlink band such as Orbcomm, Starsys, S80-1, Eumetsat, and Russia's Meteor system. We have analyzed this scenario, and we have found that the service outage condition alone prohibits the implementation of a fully competitive Little LEO system. While there are other spectrum and operation cost/complexity issues, the service outage dominates the discussion.

The Autometric Study shows that the average global operational time for the TYPSAT constellation in this system is 65%. See Attachment A. We note that the service outage is variable over time and geographic location, creating service consistency issues and adding to operations cost and complexity as noted earlier. We also note that in all cases the outage affects more than 21 of the 24 satellites in the constellation, and that it varies greatly over time. For example, in one case one satellite is operational for only 15% of a 24-hour period, while in another 24-hour period the same satellite is operational 70%. This demonstrates the dynamics of the service outage condition, and the resulting impact on operations. We also note

[12] Negotiated Rulemaking Committee Report at ¶ 12 (September 16, 1993).

that the 65% average is for the mean latitude point which falls between 35 and 45 degrees latitude, and that the outage increases at latitudes above the mean point. This means that the service outages occur at a greater magnitude in the more populated regions of the earth where the predominance of users are located, including the continental United States, so that the problem is worse than the average might imply. A service outage of 35% effectively impedes the applicant from offering the same service as the first round Little LEO licensees.

Below are comments on a variety of other technical and operational issues associated with the Little LEO-2 proposal. We address these in the following:

Methods for Sharing the Band. The TDMA/FDMA methods for frequency sharing proposed by the Commission (see Notice at ¶ 51) have inherent problems when operating across systems (intersystem operations), as noted earlier (see TDMA/FDMA discussion supra). We have indicated that these methods are insufficient for the intersystem operation promised by the Commission. With regard to sharing the service uplink, Final Analysis will use its "STARS" system, which is a high-precision dynamic frequency scanning and channel-selection system. Furthermore, as discussed above, each fully competitive Little LEO system will require dedicated feeder links that cannot be shared (see dedicated feeder link discussion supra).

Sufficient Spectrum (Notice at ¶ 53). The Notice proposes that two NOAA channels coupled with the use of the band edge is sufficient spectrum for a Little LEO system to operate. As we mentioned earlier, the TYPSAT coverage outage is caused by NOAA's overlapping constellation footprint and is irrespective of the available spectrum.

Access to NOAA Bands (Notice at ¶ 55). The Commission states that a user has access to the NOAA bands for 84.5 percent of available time. Notice at ¶ 55. This is a misleading statement and would produce incorrect results. We believe that the FCC's estimate on the coverage outage was calculated based on user visibility from a fixed point. This does not accurately model the interference potential, as a TYPSAT user may not be in view of the NOAA satellite, yet the TYPSAT footprint and the NOAA footprint may still overlap. Transmissions would not be possible with overlapping footprints.[13] For instance, as is shown in the Autometric Study, a single satellite for VITA produces an outage for the TYPSAT constellation in excess of 22 percent. For a five satellite constellation, approximately 35 percent reduction in coverage results. Extrapolating these two scenarios for a three satellite constellation would result in about 30 percent coverage outage or a factor of two increase in coverage outage over that which is estimated by the Commission. Cf. Notice at ¶ 55.

[13] For picturing the complexity of this problem, a TYPSAT footprint would exceed the size of the continental United States.

Transmission Avoidance for NOAA Satellites (Notice at ¶¶ 56-59). The Notice seeks comment on a method of avoiding interference with NOAA satellites. Final Analysis's ground system capabilities, as currently designed, permit performance of the necessary functions. Final Analysis has the capability to dynamically model the TYPSAT constellation and the NOAA satellites in terms of orbital position and transmission field of view, and to establish transmission avoidance times. Ephemeris for the NOAA and TYPSAT satellites can be updated frequently and via a variety of mechanisms as needed to assure accuracy. The accuracy of the ephemeris and the propagator will be assessed to determine the optimum frequency at which the ephemeris is provided. We do not see this as an issue. Further, the system can be adjusted with margins to further ensure transmission avoidance. These transmission avoidance times are then fed to our command planning system which generates instructions to the satellite for control of transceiver operations. We note that the redundancy in Final Analysis's system assures a high degree of reliability for single failure scenarios.

Ephemeris Transmission Method and Backup (Notice at ¶ 60). The Notice seeks comment on the preferred means of transferring ephemeris data to the Little LEO operators, (e.g., via electronic transfer or by diskette) and procedures to be undertaken in the event of unavailability of data or observed errors. An electronic transfer method of receiving ephemeris at the Final Analysis network control center is the preferred method. We have the capability today to receive such data from existing on-line services. To assure reliability, backup methods should also be established and can take the form of fax, e-mail, or diskette. As a further backup under a worst-case scenario where ephemeris is not available, Final Analysis can increase the transmission avoidance times produced by a longer term propagation from the last-known ephemeris by adding a time bias that conservatively compensates for the known error accumulation rate of the propagator. Consequently, we do not foresee any technical difficulties in performing this operation, as we have the technology today.

Paragraph 61 of the Notice seems to suggest that NOAA receivers will not be impinged with radio energy from Little LEO satellites. This is not correct. NOAA earth stations or terminals will be impinged by a Little LEO satellite when NOAA earth stations are within the Little LEO footprint at the time that it is not overlapping with a NOAA satellite's footprint.

The Commission also requests comment on the appropriateness of the use of a zero degree angle for transmission avoidance. See Notice at ¶ 61. Our view is that a zero degree angle is conservative, as most operations are conducted at five (5) degrees and above. Nonetheless, Final Analysis has used the zero degree angle in our analysis, and our systems are capable of using any positive angle or set of angles.

Reset Signal (Notice at ¶ 63). The Commission recommends a 48-hour timer aboard the satellite that would cease transmit operations for the bands shared with NOAA if a ground reset was not received within that period of time. Within Final Analysis's satellite system there are several protection mechanisms that would prevent a failed-on scenario for the 137-138 MHz transmitter. First, we operate our transmitters on a duty cycle basis, turning them off and on dynamically throughout an operational day as needed for service operations. These duty cycle operations are conducted via commands to the satellite that can be stored in the satellite computer ahead of time to control transmitter operations even without ground intervention. Included in these stored commands are fail-safe mechanisms to shut off transmitter operations in the event that a new set of stored commands are not received. Further, should the transmitter fail in the "on" condition for some reason, the power consumption would drive the satellite into a low voltage condition well before the 48-hour period is reached. The satellite contains logic in the onboard computer that detects low voltage conditions and ceases all transmitter (and other) operations. Finally, should these two mechanisms not cease transmitter operations, the satellite would likely reach a state of undervoltage at which time sufficient power to operate the transmitter would not be available, and the transmitter would cease to operate.

Consequently, Final Analysis has in place several layers of protection against a failed-on condition. Therefore, a 48-hour timer and reset function is not needed. However, we do have the technical capability to implement such an operation within our onboard computer if required. This function can be validated using the telemetry data available from the satellite.

Effect of Little LEO Transmission on the NOAA Receivers (Notice at ¶ 64). The Commission requests comment on the effect of Little LEO transmissions on NOAA receivers when they are not in use, and how any adverse impact may be mitigated. It is our belief that the NOAA receivers when not in use would see our signal, and that the receiver may actively attempt to acquire the signal. However, we are limited to low power flux density levels by ITU Radio Regulations (-125 dBW/meter^2/kHz) that will protect the NOAA receivers from any damage. Therefore, we expect no adverse impact for such reception levels, nor do we suggest any techniques for avoidance. However, we could conduct a more detailed assessment if necessary and if the technical details of the NOAA receivers were made available.

Furthermore, a reciprocal problem exists with the sharing scenario in that the NOAA satellite transmissions will affect remote user terminals ("RTs"). Specifically, the NOAA transmission will "wake up" RTs from a sleep mode for a short period at which time our RT will determine that the signal is not intended for its use, at which time it will return to a sleep mode. For remote field operations, power consumption of the RT is an issue. The constant stimulation of our RT by the NOAA satellites will increase power consumption, and therefore require more local power. The result may be an increase in RT costs and/or additional field maintenance activities to maintain a power source.

<u>Sharing and Migration Scenarios (Notice at ¶ 65)</u>. The Commission requests comment on the proposed sharing and migration scenario between the Little LEO System-2 and Metsat. First, as discussed, Final Analysis has significant concerns regarding the service outage associated with time sharing of frequency blocks. The sharing scenario is technically feasible in that the Final Analysis satellites, ground systems, and operations design will allow such an operations to occur. Final Analysis believes it is the only qualified second round applicant that can demonstrate this capability at this time.

In addition, the Commission's migration scenario projected for Little LEO-2 and the MetSats does not resolve the issues mentioned herein. At the time of migration, which is scheduled to occur in 2002, Little LEO-2 will lose exclusive use of the NOAA subbands. However, a second round TYPSAT will not have deployed a full constellation until that time. Thus, a TYPSAT will have just achieved full constellation deployment and will be prepared to offer near-real time services just at the time that the Little LEO-2 system loses exclusive use of the NOAA subbands in 2002 under the Commission's migration scenario. Therefore, the migration scenario will inhibit the development of a fully competitive system.

C. Little LEO-3

<u>Little LEO-3 Issues (Notice at ¶¶ 68-69)</u>. The Commission proposes that Little LEO-3 would share its uplink frequencies with US and Russian RNSS systems (and the potential for additional coordination with France), and have two 50 kHz segments. Final Analysis has several significant concerns with this proposed system.

<u>Insufficient Spectrum</u>. The proposed system does not have sufficient uplink spectrum for a fully competitive system. The Commission proposes 100 kHz of uplink spectrum. As noted above, each system would require a minimum of 50 kHz of dedicated spectrum for each feeder link (three satellites within the same footprint at the same time would require 150 kHz of dedicated spectrum for each feeder link operation). Use of the Little LEO-3 uplink for feeder links does not leave any spectrum for the service uplink. Moreover, sharing with the Russian RNSS would further reduce available spectrum.

<u>Coordination with the Russian RNSS</u>. From our involvement in the ITU activities, we are aware of the Russian RNSS systems and their objectives in protecting their systems from the potential interference with Little LEO systems. We understand that the Russians are asking for no interfering Little LEO transmissions over the oceans and major waterways, and a substantial land border along these bodies of water. Service outages resulting from sharing with the Russian RNSS system would be similar (in major waterways) with service outages resulting from sharing with NOAA or DoD.

Little LEO-3 Coverage Outage Issue (Notice at ¶ 70). The Autometric Study employed a model using five sun-synchronous meteorological satellites which characterize both the NOAA system and the DoD system. In the previous section discussing Little LEO-2, we mention that this five-satellite constellation causes a 35 percent coverage outage into a typical satellite constellation (TYPSAT).[14] This was based on a zero-degree elevation angle. A less than zero degree elevation angle (as proposed in the Notice at ¶ 71) increases the coverage outage by a substantial amount.

We believe that the FCC's estimate on the coverage outage was calculated based on user visibility from a fixed point. This does not accurately model the interference potential, as a TYPSAT user may not be in view of the DoD satellite yet the TYPSAT footprint and the DoD footprint may still overlap. Transmissions would not be possible with the overlapping footprints. For picturing the complexity of this problem, a TYPSAT footprint would exceed the size of the continental United States.[15]

Moreover, in Final Analysis's opinion, access to 100 percent of spectrum 65 percent of the time is not the same as access to 65 percent of spectrum 100 percent of time. A sizable reduction in the time of access as suggested in the Notice would inhibit the ability to cover market segments that are time sensitive.

The Commission seeks comment on how the Little LEO system could best use the remaining available time based on a DoD system composed of five satellites. To fully utilize the coverage available outside of the DoD satellite footprint, Final Analysis has the capability to dynamically model its constellation and the DoD satellites in terms of orbital position and transmission field of view. Ephemeris for the DoD and the Final Analysis satellites can be

[14] This outage is irrespective of the amount of available spectrum and is directly related to the overlapping footprints of the satellite constellations.

[15] The Commission states in the Notice at ¶ 70 that a user has access to a DoD three-satellite system for approximately 15.5 percent of the time, and therefore asserts that the remaining 84.5 percent of available time, or about twenty hours per day would be used by the Little LEO system-3. These are misleading statements and would produce incorrect results. For instance, as was shown in the Autometric Study, a single satellite for VITA produced an outage for TYPSAT constellation in excess of 22 percent. For a five satellite constellation, approximately 35 percent reduction in coverage results. Extrapolating these two scenarios for a three satellite constellation would result in about 30 percent coverage outage or a factor of two increase in coverage outage over that which is estimated by the Commission in the Notice at ¶ 70. Likewise, the numbers with a four satellite constellation system are similarly misleading.

updated frequently and via a variety of mechanisms as needed to assure the accuracy. The accuracy of the ephemeris and the propagator will be assessed to determine the optimum frequency at which the ephemeris is required. Final Analysis's system redundancy can assure a high degree of reliability for single failure scenarios.

Little LEO-3 Issues Presented in Notice at ¶ 71. The Notice proposes inclusion of an elevation angle of less than zero degrees. Although Final Analysis believes that it may not be necessary to have protection below the zero-degree mask, Final Analysis can in fact implement such a mask by adding time to the footprint boundaries, which thereby provides the additional protection zone suggested in the Notice.

The Notice also requests commenters to provide a description of their propagator algorithms that they expect to use with their NVNG MSS systems. Final Analysis uses the Omni software which makes use of the SGP4 propagation algorithm to calculate satellite positions which is used extensively by NORAD and U.S. Space Command.

Little LEO-3 Issues Presented in Notice at ¶¶ 72-4. The 90-minute frequency change requirement will require additional operations team support, a dedicated voice and/or electronic link to DoD, and up to six (6) additional ground stations to command the satellite to change its frequency in the required 90 minute interval (single string configuration only; more sites are required should DoD require redundancy for higher reliability in affecting the change as directed). Further, and more importantly, the need to operate on two possible frequencies approximately 1 MHz apart will require enhancements to the RT receiver so that it can be activated upon receipt of a beacon signal operating at either frequency. This will increase the cost and complexity of the RT.

Final Analysis satellites (including FAISAT-2V authorized under an experimental license) have the capability to adjust to the required frequencies. We can make such a change within 90 minutes for the near-polar satellites, but for lower inclination satellites it requires longer periods with our currently planned ground stations.

Little LEO-3 Issues Presented in Notice at ¶ 75. A ninety-minute implementation period requires additional ground stations, and additional operations staff. The increased cost, operations complexity, and potential for service interruptions resulting from the Commission's proposed spectrum sharing system will create an unfair disadvantage within the second round applicants, raises the cost of service to the public, increases the barriers to entry, and further disrupts the development of a fully competitive environment.

The Commission proposes to require that a Little LEO-3 licensee successfully coordinate its system with DoD prior to launch and operation of a licensed system. The

Commission also proposes to require that, at DoD's instruction, the Little LEO-3 operator test, up to four times a year, its systems ability to implement a DoD-requested frequency change. Final Analysis is preparing for shipment of the FAISAT-2V to Russia and expects to launch the satellite in the first quarter of 1997. Final Analysis is the only qualified second round applicant that can make such a demonstration and coordination at this time.

IV. CONCLUSION

Accordingly, our technical review shows that each of the systems proposed in the Notice has its own particular limitations due to system outages. Little LEO-1 would not support a commercially viable Little LEO system. While Little LEO-2 and Little LEO-3 may support commercially viable operations, they possess constraints that would hinder the development of a fully competitive Little LEO system. Furthermore, Little LEO-3 imposes additional costs on ground segments. In sum, the system outages in the Commission's proposals would seriously constraint competitiveness across all market segments.

Furthermore, the Commission's proposals do not take into account specific needs of Little LEO operations for (i) dedicated feeder links; and (ii) proportionally more uplink than downlink. To the extent that system outages will result from sharing in each of the proposed band plans, there is not much reason not to divide up the spectrum further in order avoid mutual exclusivity. Slightly different spectrum pairings may alleviate some of the problems posed by the Commission's proposals.

ATTACHMENT A

Introduction to Autometrics Study

Autometric, Inc. (Colorado Springs, CO) is a company servicing the needs of both government and private enterprise in sensor planning, photogrammetry, and complex information systems. Final Analysis requested Autometric to perform a system study on the outages caused by the restrictions placed on frequency spectrum use by the Notice's proposals. The system software used by Autometric is called "Omni" and was developed by Autometric to serve the needs of the Department of Defense. The system software provides the means to visualize the results of complex simulations involving spatial relationships between user-defined objects such as satellites, aircraft, ground sensors and missiles. The system software is mature and available as a COTS product to support 2D and 3D simulations.

The Omni software makes use of the SGP4 propagation algorithm to calculate satellite positions and is used extensively by NORAD and the U.S. Space Command. Orbital parameters for actual satellites can be imported in the standard two-card element set format and notional satellites may be user-defined via data entry windows.

The statement of work for the Autometric contract requested study of the outages caused by the restrictions placed on the use of the NOAA and DOD shared bands for the systems "Little LEO-2" and "Little LEO-3" proposed in the Notice. A typical 24 satellite LEO constellation, called TYPSAT, was studied with orbital planes at 45 degree spacing and 6 satellites per plane operating at an altitude of 1,000 kilometers. The constellation representing the DOD and NOAA systems is composed of five satellites spread at two hour local time spacing in sun synchronous orbits. This constellation represents both tet NOAA constellation proposed for Little LEO system 2 and the DOD constellation proposed for Little LEO system 3.

Two hour spacing was assumed to provide worst case scenario for the spectrum outage study.

The outage suffered by the Little LEO constellation when interfered with by the single VITA satellite is 22% on a global average basis with the number increasing as ground operation site is moved north or south of the nominal latitude. For the 5 satellite constellation representing the NOAA or DOD constellations, the outage suffered by the TYPSAT constellation approximates a 35% of operation time on global average basis. The study was conducted for four 24-hour periods and represents 3, 6 and 9 months of orbit propagation.

Autometric
INCORPORATED

FCC Satellite Interference Study
for
Final Analysis Inc.

Prepared by
Autometric, Inc.

November 15, 1996

FCC Satellite Interference Study
for
Final Analysis Inc.

Prepared by
Automatric, Inc.

November 15, 1996

NPRM Interference Study

Problem Statement

Autometric was requested to perform an analysis of satellite interference between a typical 24 satellite (4 planes of 6 satellites each) constellation, hereafter referred to as TYPSAT constellation and the VITASAT-1R satellite, as well as a notional NOAA 5-satellite constellation. For the purpose of this study, interference was considered possible anytime the zero-degree elevation angle footprints of the satellites intersected.

Methodology

The study was conducted using the Omni visualization tool. Omni sensors are able to detect objects which fall within their defined volume; however, one sensor volume is not able to detect another volume directly. In order to determine when sensor volumes overlap, several approximations to the physical geometry had to be made. These approximations assume a spherical earth model and perfectly circular orbits of the satellites. These approximations do not appear to affect the results by more than ± 1 minute, which is the time step at which the simulation was run.

Due to the different orbit geometries of the interacting constellations, no one observation period will necessarily provide a picture of their interference which is valid at other times. Orbits at different inclinations and altitudes will precess at different rates. Thus the two constellations effectively "drift" across one another. To compensate for this, our study examined each constellation pair at four different periods. The interaction results during these periods are expected to bound the various interaction results possible. The following pages describe the four periods studied.

Period 1 – Orbits roughly aligned, Satellites traveling in phase

Figure 1 shows ground traces for this arrangement of theTYPSAT and NOAA constellations. (Satellite positions are indicated by their numeric label, with traces displaying past positions behind them.) During this period, satellites from both constellations ascend and descend together around the globe. This period is expected to affect a few satellites for long periods of time.

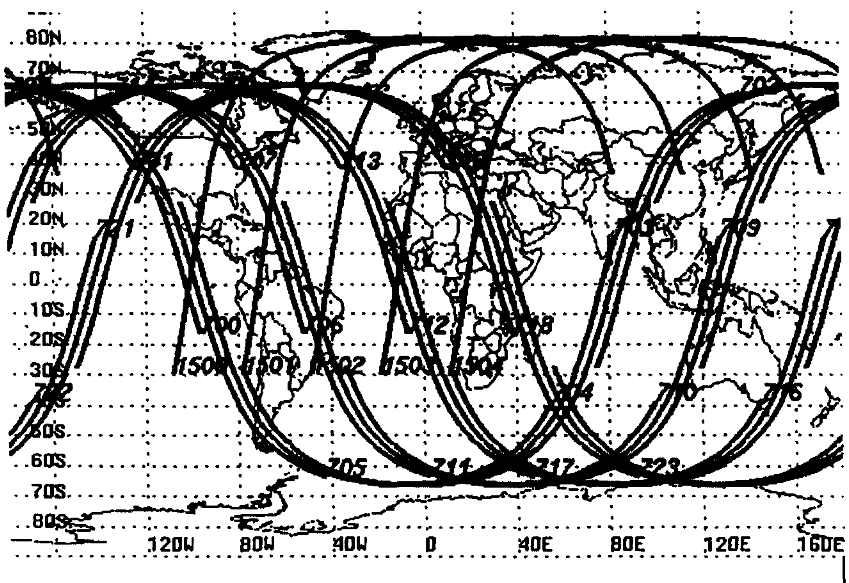


Fig. 1 – Period 1 Arrangement

Period 2 – Orbits roughly perpendicular

Figure 2 shows ground traces for this arrangement of theTYPSAT and NOAA constellations. During this period, the NOAA satellites (numbered 1500-1504) descend through the "gap" in the TYPSAT constellation in the northern hemisphere. NOAA sats interact with both ascending and descending TYPSATs.

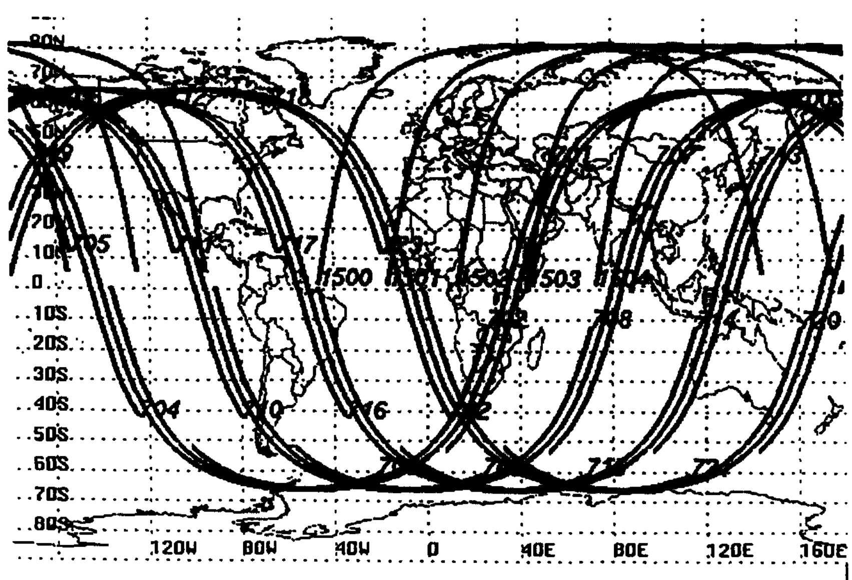


Figure 2 – Period 2 Arrangement

Period 3 – Orbits roughly aligned, satellites traveling out of phase

Figure 3 shows ground traces for this arrangement of the TYPSAT and NOAA constellations. During this period, satellites from both constellations ascend and descend opposite of one another around the globe. This arrangement is expected to affect a greater number of sats for shorter periods of time.

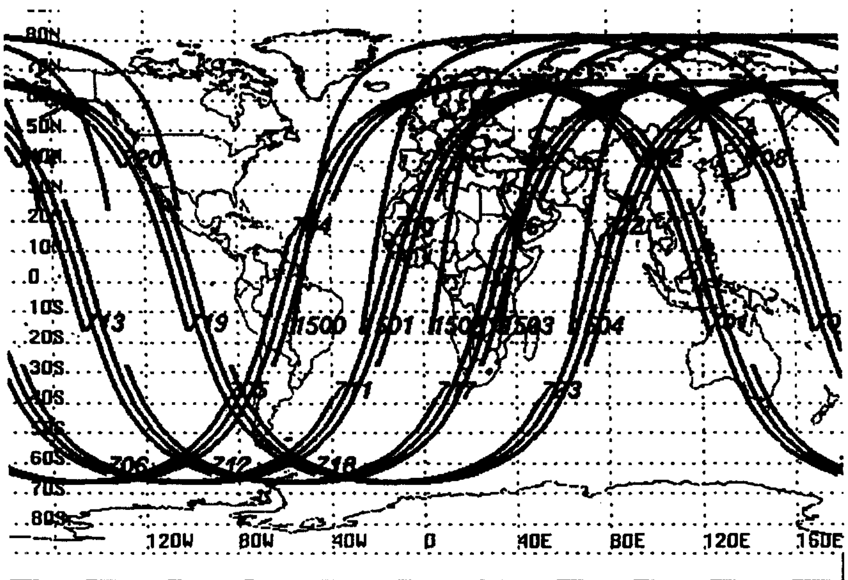


Figure 3 – Period 3 Arrangement

Period 4 – Orbits roughly perpendicular

Figure 4 shows ground traces for the final arrangement of the TYPSAT and NOAA constellations. During this period, the NOAA satellites (numbered 1500-1504) descend through the "gap" in the TYPSAT constellation in the southern hemisphere. NOAA sats interact with both ascending and descending TYPSATs.

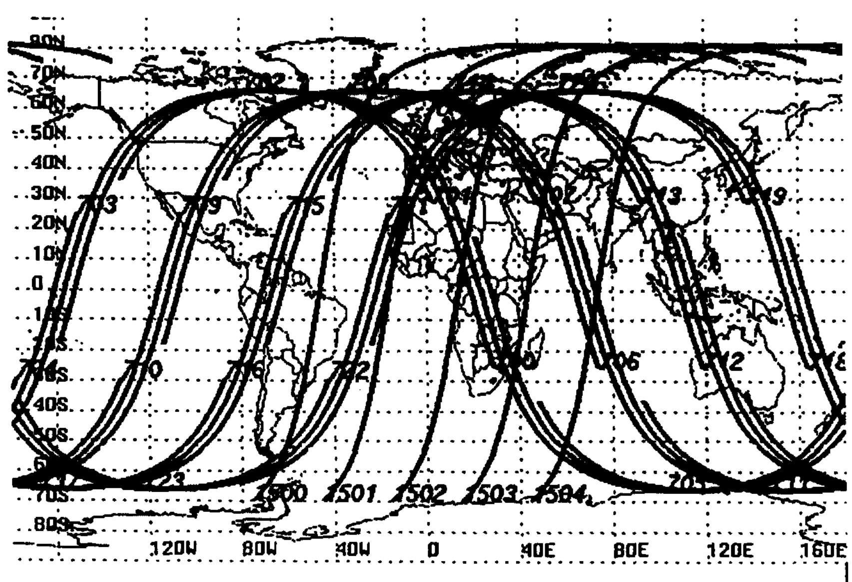


Figure 4 – Period 4 Arrangement

Similar periods were selected for the TYPSAT – VITASAT-1R study to bound the magnitudes of interaction between those systems as well. Data was collected for an arbitrary 24 hour time span in each of the four Periods.

The orbital parameters for the satellites used in the studies are presented in the table below.

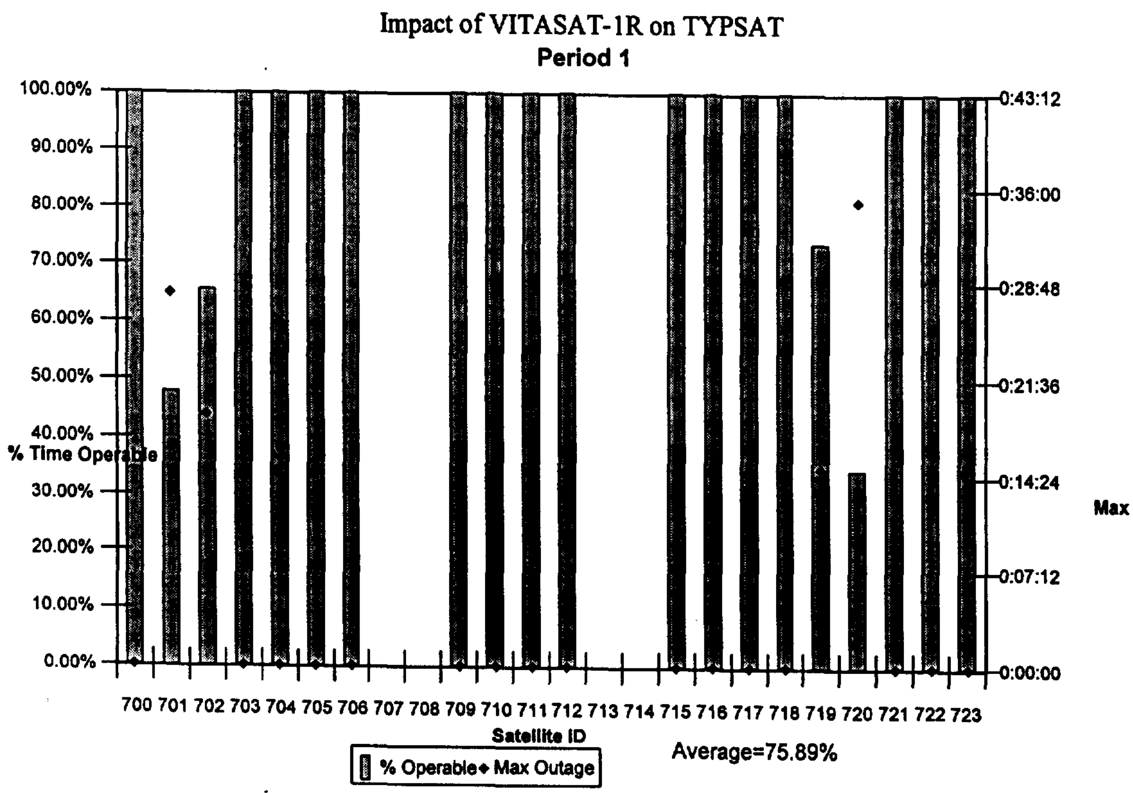
Sat ID	Alt (km)	Inc (deg)	Ecc	ArgP (deg)	RAAN (deg)	M (deg)
VITASAT-1R	1000	83	0	0	0	0
TYPSAT 1	1000	66	0	0	0	0
TYPSAT 2	1000	66	0	0	0	60
TYPSAT 3	1000	66	0	0	0	120
TYPSAT 4	1000	66	0	0	0	180
TYPSAT 5	1000	66	0	0	0	240
TYPSAT 6	1000	66	0	0	0	300
TYPSAT 7	1000	66	0	0	45	0
TYPSAT 8	1000	66	0	0	45	60
TYPSAT 9	1000	66	0	0	45	120
TYPSAT 10	1000	66	0	0	45	180
TYPSAT 11	1000	66	0	0	45	240
TYPSAT 12	1000	66	0	0	45	300
TYPSAT 13	1000	66	0	0	90	0
TYPSAT 14	1000	66	0	0	90	60
TYPSAT 15	1000	66	0	0	90	120
TYPSAT 16	1000	66	0	0	90	180
TYPSAT 17	1000	66	0	0	90	240
TYPSAT 18	1000	66	0	0	90	300
TYPSAT 19	1000	66	0	0	135	0
TYPSAT 20	1000	66	0	0	135	60
TYPSAT 21	1000	66	0	0	135	120
TYPSAT 22	1000	66	0	0	135	180
TYPSAT 23	1000	66	0	0	135	240
TYPSAT 24	1000	66	0	0	135	300
NOAA 1	850	98.6	0	0	197	0
NOAA 2	850	98.6	0	0	227	0
NOAA 3	850	98.6	0	0	257	0
NOAA 4	850	98.6	0	0	287	0
NOAA 5	850	98.6	0	0	317	0

Results

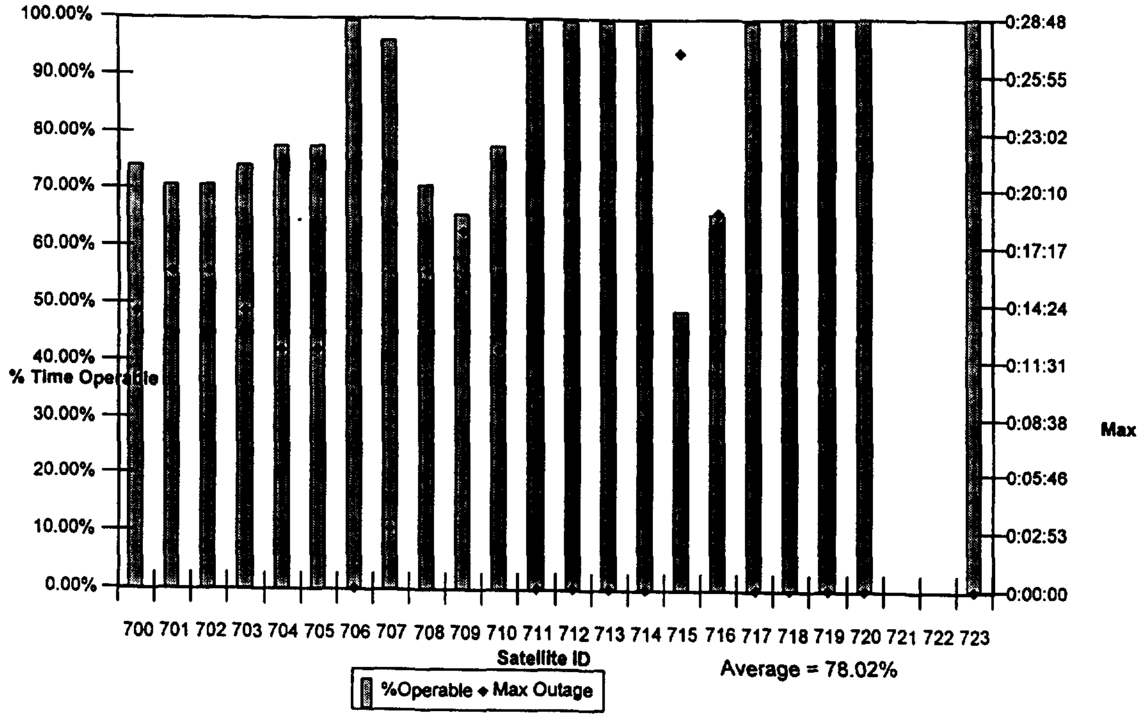
The results of these studies are presented in the graphs which follow. The TYPSAT vs. VITASAT-1R results consist of four graphs, one for each period, as do the results of the TYPSAT vs. NOAA study.

TYPSAT vs. VITASAT-1R

As expected, Period 1 provided the most drastic interference with four TYPSATs obstructed for the entire 24 hour period examined, four others operational from between 35-73%, and all other satellites unaffected. Period 3 showed all but five sats obstructed at some time but still operable between 65-85% of the time. Periods 2 and 4 showed results between these extremes, as expected. **Average operational time for the TYPSAT constellation across all four periods was 78.14%.**



Im Impact of VITASAT-1R on TYPSAT
Period 2



Impact Impact of VITASAT-1R on TYPSAT
Period 3